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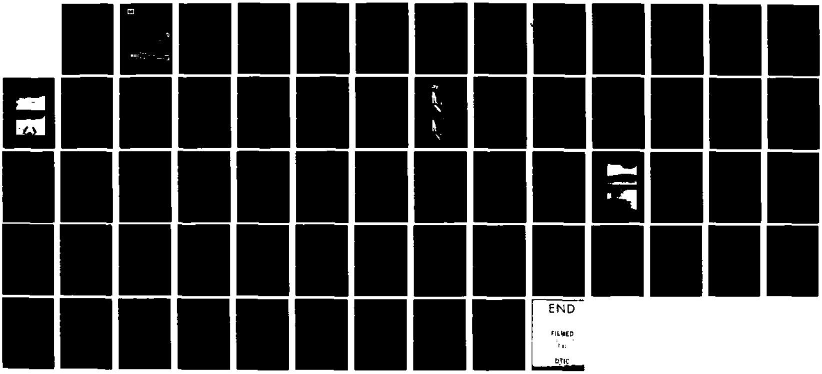

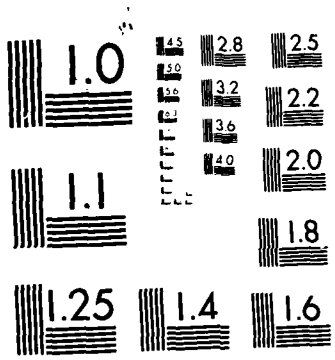
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DESIGN OF A GRAVEL BAR HABITAT FOR THE TOMBIGBEE RIVER NEAR COLUMBUS, MISS.

by

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Final Report

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A gravel habitat consisting of four gravel bars separated by pools was designed for possible placement in a river bendway at river mile 232.9 on the Tombigbee River below Columbus Lake near Columbus, Mississippi. The site is immediately downriver of a minimum-flow release structure in Columbus Dam that passes 200 cfs of surface water from Columbus Lake. The design of the artificially placed habitat was based in part on biological and physico-chemical characteristics of an existing gravel bar in the Buttahatchie River and in part on the characteristics and constraints of the river (Continued)

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bendway where it is to be placed. Technical literature and reports of previous studies on the Buttahatchie and Tombigbee Rivers were also utilized. Because of favorable physical, chemical, and biological characteristics of the incoming lake water and the physically diverse nature of the proposed habitat, a dense and diverse invertebrate fauna including many species of common and uncommon mussels would be expected to inhabit this area.

The artificially placed habitat will consist of four gravel bars, each 150 ft long, separated by pools that will be about 100 ft long and 5 ft deep. The habitat will be constructed by placing fill material into the bendway, then capping the fill material with specific sizes and mixtures of gravel and sand to develop four bars separated by pools. Bar I will be composed mostly of coarse gravel and cobbles (1 to 5 in. in diameter); bar IV will consist mainly of sand with small amounts of 1- to 3-in.-diameter gravel. Intermediate sizes and mixtures of material will be used in bars II and III.

A single cut will be made across the top of each gravel bar; water in the bendway will flow over the bar and through these channels. Constricting the width and depth of the bendway by placement of the fill and gravel caps will increase the velocity of the water. The average velocity over bars I, II, and III will be 1.5 fps; above the last gravel bar, water will move at about 1 fps. The water velocity should be sufficient to remove the majority of settled clay or silt particles but not to erode the parent gravel/sand mixture composing each bar.

PREFACE

The study described in this report was sponsored by the U.S. Army Engineer District, Mobile. This document presents a proposed plan for the construction of a gravel bar habitat to be placed in a bendway of the Tombigbee River at river mile 232.9 near Columbus, Mississippi.

This report was prepared by Dr. Andrew C. Miller and Dr. Robert H. King of the Aquatic Habitat Group (AHG) and Mr. Ed Glover of the Hydraulics Laboratory (HL) of the U.S. Army Engineer Waterways Experiment Station (WES). Dr. King is an aquatic biologist on the faculty of Central Michigan University (CMU) in Mount Pleasant, Michigan. He held a temporary appointment at WES (1 August 1981 to 31 July 1982) through the Intergovernmental Personnel Act (IPA) with CMU. Mr. Glover, assisted by Mr. Ron Wooley of the HL, WES, developed the engineering design for the gravel bar habitat and prepared the engineering description of the bars. Verification of all the mussels and assistance in the field during the study of the existing bar in the Buttahatchie River was provided by Dr. Paul Yokley, University of North Alabama, Florence, Alabama. Mr. Jerry Jones, Analytical Laboratory Group, WES, coordinated the laboratory analyses of water and sediment and provided information on their methodology. Mr. Jack Mallory, Biologist with the U.S. Army Engineer District, Mobile, supplied considerable background information on the study areas and critically read a first draft of this report. Dr. Arthur Clarke, ECOSEARCH, reviewed the report and provided constructive criticism of the design plan.

This work was conducted under the general supervision of Dr. T. D. Wright, Chief, AHG, and Mr. Bob O. Benn, Chief, Environmental Sciences Division (ESD). The AHG and ESD are part of the Environmental Laboratory at WES of which Dr. John Harrison is Chief.

The Commanders and Directors of WES during the study and the preparation of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. Fred R. Brown.

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DESIGN OF A GRAVEL BAR HABITAT FOR PLACEMENT ON THE TOMBIGBEE RIVER NEAR COLUMBUS, MISSISSIPPI

PART I: INTRODUCTION

Background

1. The Tennessee-Tombigbee Waterway (TTW), authorized by Public Law 525 in accordance with recommendations contained in House Document 486 of the 79th Congress, was designed to provide a more direct shipping route between the eastern Gulf Coast and the mid-continental United States. This is being accomplished by connecting the upper portion of the Tombigbee River to the Tennessee River in extreme northeastern Mississippi. The TTW project will convert the free-flowing Tombigbee River into a series of run-of-the-river reservoirs. In addition, maintenance dredging, coupled with alteration of the fluctuation in water velocities and levels, will encourage slack-water aquatic species at the expense of organisms that normally inhabit riffles and gravel substrate.

2. The Tombigbee River, including the portion that flows through Columbus, Mississippi, has long been known by professional malacologists (those that study mollusks) and amateur shell collectors as an area that supports a rich and diverse assemblage of freshwater mussels. The majority of the mussels taken from the river are fairly thick-shelled species that commonly inhabit substrates covered by rapidly moving water. Typically, these organisms congregate in groups or beds usually found on gravel shoals or bars in rivers. A typical gravel bar is composed of a mixture of sand, silt, and various sizes of gravel and provides a fairly stable substrate to which a mussel can anchor firmly and yet still move about fairly easily. In addition to the freshwater mussels, many other aquatic organisms including snails, aquatic worms, insects, and fish such as sculpins, darters, and minnows are common inhabitants of gravel bars.

3. Aside from their interest to professional malacologists and shell collectors, the freshwater mussels are a unique resource and have commercial and ecological value. Shells of certain species are collected and shipped to the Orient where they are cut into cubes, pressure-ground into spheres, and inserted into oysters to become nuclei of freshwater pearls. In addition, the shells of certain species (e.g., *Proptera alata*) are used for jewelry. Historically,

the shells of freshwater mussels have been used since the late 1800s for the pearl button industry (Parmalee 1967). In addition to their commercial and historic interest, the freshwater mussels often form a major component of the benthic (or bottom-dwelling) biomass in a lake or stream. These organisms process particulate organic matter, provide a substrate for attached algae, and are a source of food for certain fish (freshwater drum and catfish), birds (great blue heron), and mammals (muskrats and raccoon).

4. Currently there are 25 species of freshwater mussels listed on the US Department of Interior list of threatened and endangered species. Based upon the Endangered Species Act of 1973 as amended, it is illegal to harm one of these protected organisms by habitat modification or by collecting for commercial or other purposes. In addition, the US Department of the Interior is reviewing the status of five other uncommon mussels, all of which have been collected at one time or another in the Mobile River Basin, specifically in the Tombigbee River and certain tributaries in the Columbus area (see Federal Register 11 August 1980).

Purpose and Scope

5. At the request of the U.S. Army Engineer District, Mobile, a meeting was held on 13 November 1980 at the Waterways Experiment Station (WES). The purpose of the meeting was to discuss the feasibility of scientists at WES developing a plan for an artificially placed gravel bar habitat. The gravel bar habitat would be established in a bendway of the Tombigbee River (river mile 232.9) directly below the minimum-flow release structure in Columbus Dam near Columbus, Mississippi. The site was chosen because it was outside the navigation route for the TTW and it would receive a constant year-round flow of water (200 cfs) from the minimum-flow release structure. In addition, the bendway will be protected from high water velocities which accompany high discharge in the Tombigbee River. The primary objective of creating the gravel bar habitat was to provide a source of food and cover for riffle-inhabiting species of fish, aquatic insects, and other benthic invertebrates. It was also concluded that this area could be used by many species of naturally occurring mussels.

6. This report presents a proposed design for a gravel habitat to consist of a series of bars and pools to be developed below Columbus Lake

at Columbus, Mississippi. The plan includes information on location, recommended substrate types, areal extent, water depths, and velocities for the gravel bar habitat, as well as the type of organisms likely to colonize the habitat.

7. To the best of our knowledge the concept of constructing habitat for mussels is new. While many commercial shell fishermen transplant mussels to new areas and mussel relocation has been carried out in the Mississippi River at Rock Island, Illinois, we know of no structured effort to develop a habitat for these species. Such is not the case for sport fishes, where ladders, spawning bars, and attractors are commonly used to enhance the fishery. It is our opinion that the proposed habitat will provide a unique area for colonization by aquatic organisms as well as a site for future studies by freshwater ecologists. In this area substrate composition, water depth and velocity will be known. Changes in substrate composition and discharge as well as colonization rates by aquatic organisms can be readily monitored from the time the habitat complex is in place. To lay the proper bases for possible detailed studies at a later time, the authors have included the results of the baseline study (Appendix A & B) which preceded this work.

PART II: DESCRIPTION OF THE STUDY AREA

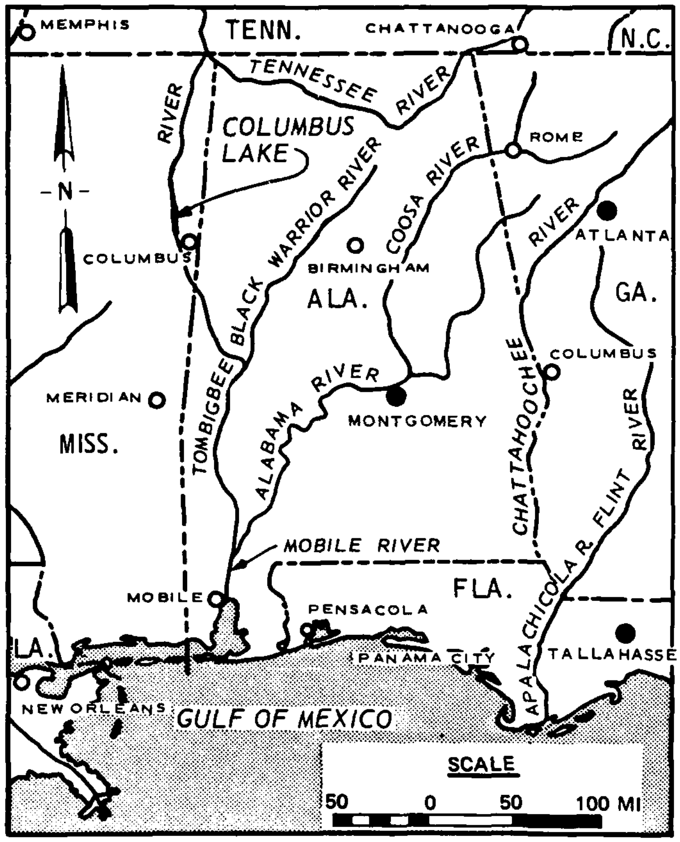
Gravel Bar Site on the Tombigbee River

8. The Tombigbee River originates in northeastern Mississippi, flows along the eastern portion of the state, then moves into Alabama south of Columbus (Fig. 1). It is joined by the Black Warrior River at Demopolis, Alabama, and then by the Alabama River further south. The confluence of the Alabama and Tombigbee rivers forms the Mobile River, which enters Mobile Bay, an inlet of the Gulf of Mexico.

9. The Tombigbee River is a medium-sized river that experiences frequent and dramatic fluctuations in discharge. For the periods of record (October 1899 to December 1912, August 1928 to current year), discharge at Columbus ranged from 138 cubic feet per second (cfs) to 194,000 cfs; the average for this time period was 6,458 cfs. These changes in water levels were brought about by precipitation, which consisted almost entirely of rainfall. In the Columbus area the wettest months are usually December through April; average rainfall for the year is about 54 in.

10. On the west side of Columbus Lake is a minimum-flow release structure that directs water from the lake into an isolated bendway that terminates at Columbus Dam (Figs. 2 and 3). The structure passes 200 cfs of surface water from the lake and carries it under the dam where it enters a riprapped flume. The lake water then flows down the flume and into the upper most portion of the bendway. The bendway, which is less than a mile long, was isolated by the placement of the Columbus Dam. The lower end of the bendway connects with the navigation channel about a half a mile down river of the lock structure. When the TTW is complete, navigation traffic will bypass this bendway and move directly to and from the lock. However, fishing and pleasure boats can and probably will move up and down the bendway to the point where flow from the riprapped flume enters.

11. The only significant source of flowing water in the bendway below Columbus Lake is the minimum-flow release structure located in Columbus Dam. Since the lower end of the bendway connects with the Tombigbee River, water levels in the bendway respond to changes in the river stage. However, because the upper end of the bendway terminates at the lower face of Columbus Dam, there is no continuous flow of Tombigbee River water through the bendway. Although



VICINITY MAP

Fig. 1. Course of the Tombigbee River

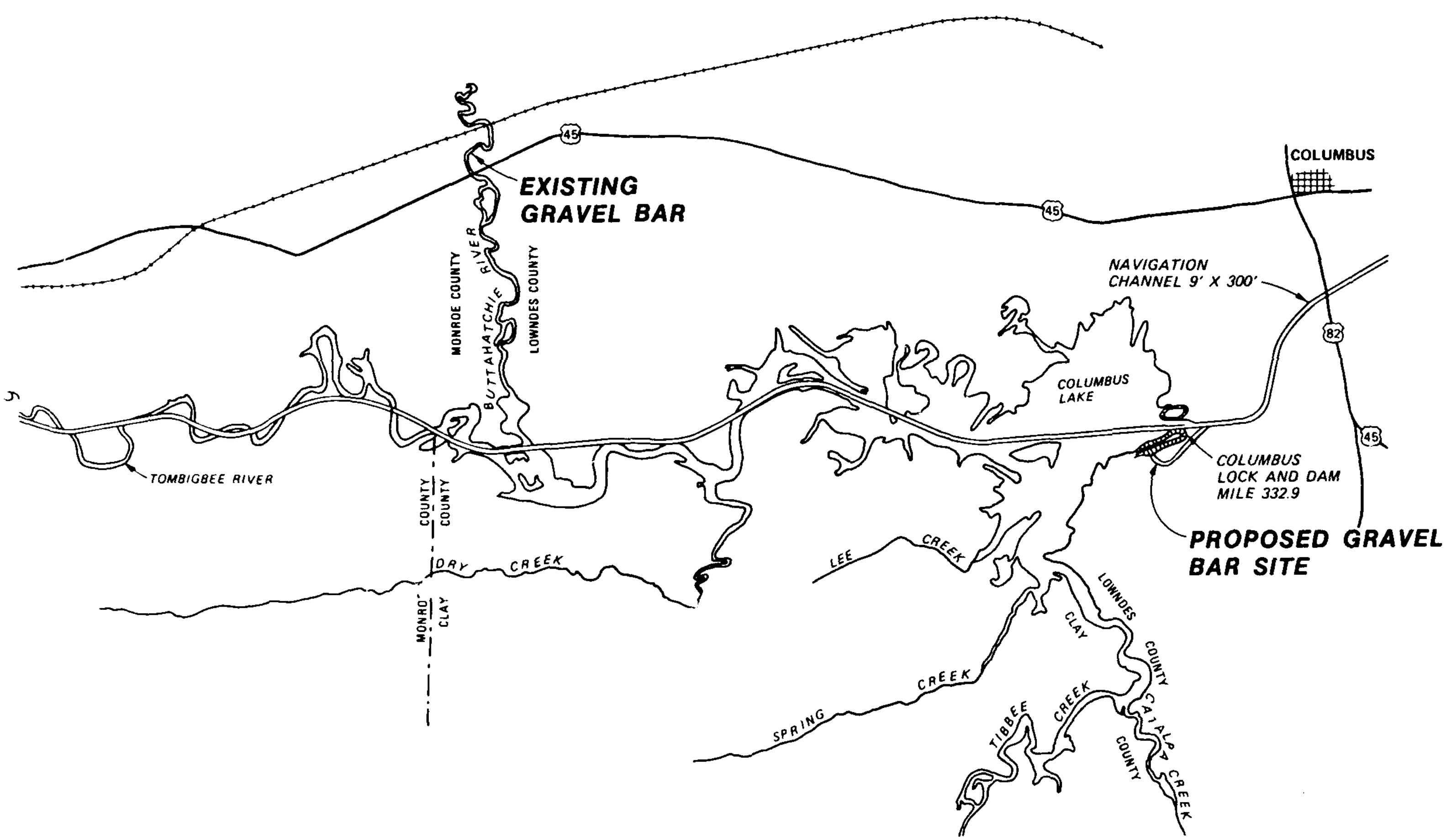


Fig. 2. Locations of existing and proposed gravel bars

a. Release structure

b. Discharge flowing through riprapped channel into isolated bendway of the Tombigbee River

Fig. 3. Minimum-flow release structure in Columbus Dam (a) and outfall area (b)

the minimum-flow release structure releases 200 cfs of lake water into the upper end, this causes no measurable current except in the upper 50 to 100 yds of the bendway. The depth and width of the bendway channel are such that 200 cfs of incoming lake water has virtually no influence on water movement throughout most of this area.

Existing Gravel Bar on the Buttahatchie River

17. The first phase of this study was to examine a naturally occurring gravel bar in the general vicinity of the experimental area. The final design of the gravel habitat was based in part on findings at a gravel bar on the Buttahatchie River (Fig. 2). It was recognized that the bar was on a different stream than the Tombigbee River; however, it was judged that the Buttahatchie River gravel bar would be very similar in water depths and velocities and substrate composition to conditions planned at the site on the Tombigbee River. In addition, recent maintenance dredging below Columbus Dam made it impossible to find a naturally occurring gravel bar with indigenous mussel fauna.

18. The Buttahatchie River in the vicinity of the existing gravel bar was about 120 ft wide. The existing bar was about 70 ft long and 40 ft wide. Downriver of the bar, water depths ranged from about 2 in. to 35 in. and water velocities from 0.3 feet per second (fps) to about 3.0 fps. The surface of the bar was flat and consisted of medium sized (1 to 3 in.) fairly smooth gravel mixed with small amounts of sand and mud. The emergent vascular plant *Dianthera americana* grew along the periphery of the upper portion of the bar.

19. For a map and photographs of the existing bar on the Buttahatchie River, see Figures A1 and A2 in Appendix A. Methods, materials, and results of the ecological studies conducted at the existing gravel bar on the Buttahatchie River and the proposed gravel bar site on the Tombigbee River are contained in Appendix A and B, respectively.

PART III: PROPOSED GRAVEL BAR HABITAT

20. This section presents the design plans for artificially placed gravel habitat intended for the Tombigbee River below Columbus Lake near Columbus, Mississippi. The conceptual base of the plan was developed as a result of studies that took place on the Buttahatchie and the Tombigbee rivers (see Appendix A and B). Additional information was obtained from the technical literature and findings from an ongoing work unit on freshwater mussels.

21. As described earlier, a minimum-flow release structure removes up to 200 cfs of surface water from Columbus Lake and directs it into a bendway partially isolated by construction of the TTW. The lower end of the bendway joins the Tombigbee River; however, the upper end terminates at the face of Columbus Dam. Because this old channel of the river is quite deep and wide, the entrance of 200 cfs of lake water via the minimum-flow release structure causes virtually no current in the bendway.

Design Plans

22. The first step in construction of the gravel bar complex will be to fill the upper 900 ft of the old bendway (Fig. 3b) to an elevation of 130 ft (Fig. 4). The required fill material could be any stable mixture of sand or gravel that could be easily obtained and transported to the area. Four distinct gravel bars will then be created by capping the fill material with specific sizes and mixtures of gravel or sand (see Table 1 for specific information on each gravel bar). Each cap of gravel (gravel bar) will be approximately 150 ft long and 170 ft wide (the width of the channel).

23. The uppermost elevation of each bar will be at 137 ft msl, 1 ft above minimum water levels for this pool. However, a channel* will be cut directly through the top of each gravel bar to allow for passage of water (Fig. 5). Elevations in each channel will vary among the bars (see Figs. 4 and 5) and from side to side within each channel so that at minimum pool water will vary

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* The channel across each bar will provide habitat for mussels and other nonmotile organisms (see Paragraph 25).

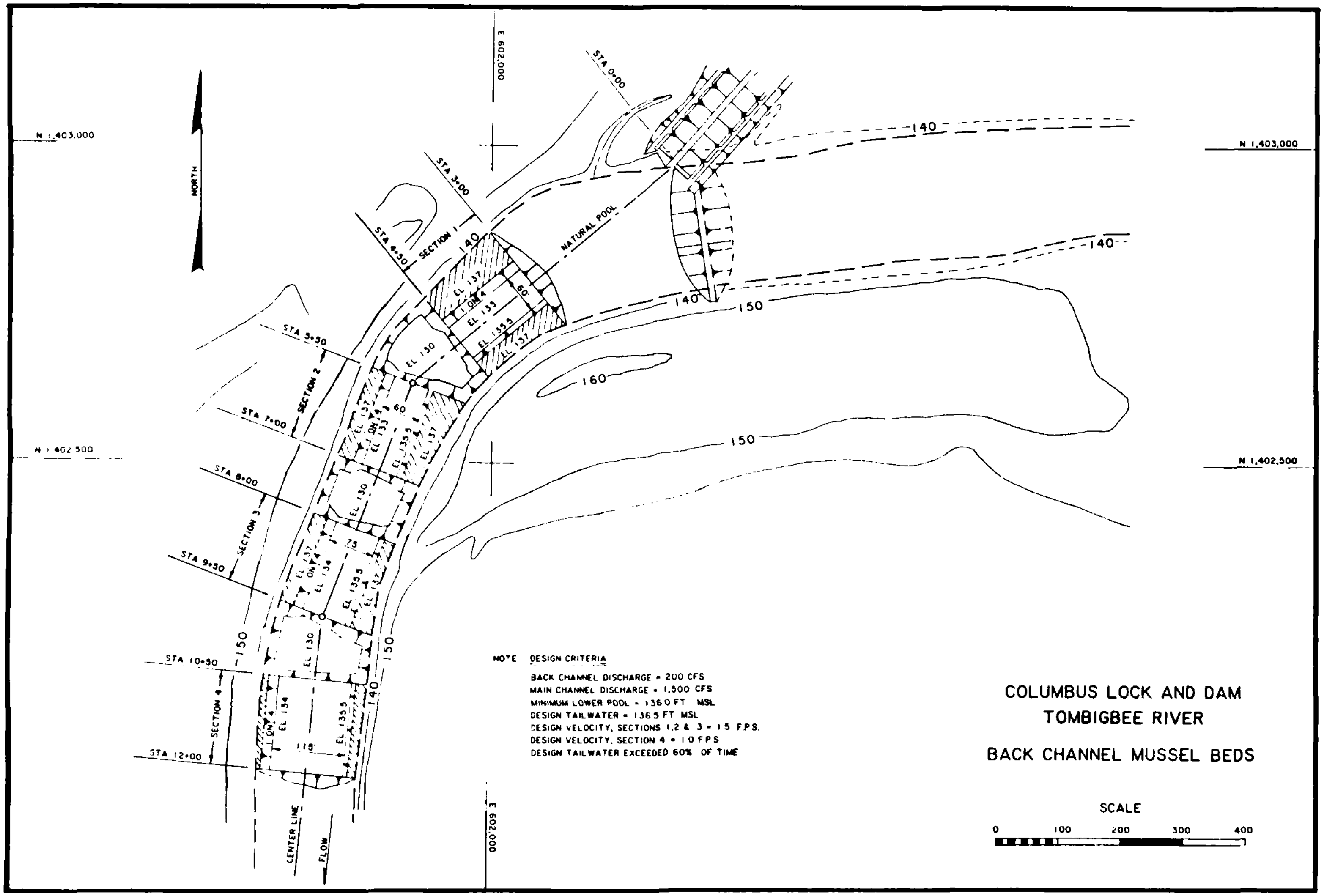

Fig. 4. Design plans for proposed gravel bars, to be located at sections 1 through 4 of the bendway on the Tombigbee River.

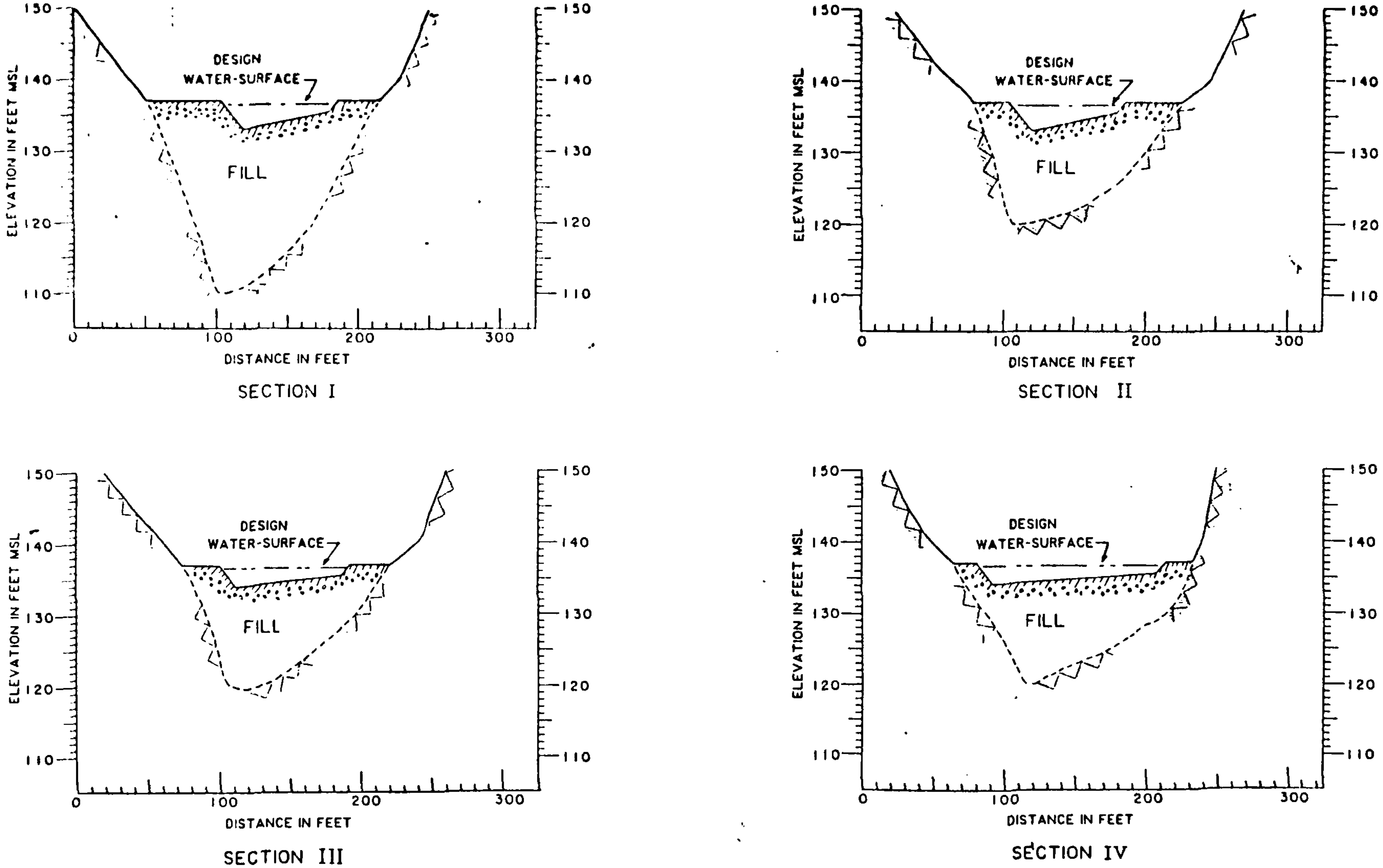

Fig. 5. Transverse sections of proposed gravel bars.

Table 1

Physical Characteristics of Proposed Gravel Bar Habitat

Parameter	Description			
	Bar I	Bar II	Bar III	Bar IV
Bar length, ft	150	150	150	150
Bar width, ft	175	175	175	175
Channel width, ft	60	60	75	115
Channel depth, ft	1.5-3.9	1.5-3.9	1.5-2.9	1.5-2.9
Substrate				
Description				
(Composition, %)				
Gravel, in.	1-5 (80)	1-3 (60)	1-3 (40)	1-3 (20)
Sand	(20)	(40)	(60)	(80)
Water velocity, fps	1.5	1.5	1.5	1.0

from 1 to 4 ft deep. The constriction of the bendway caused by placement of fill material and the gravel caps will increase the water current across the top of each gravel bar. In bars, I, II, and III, the flow will be maintained at 1.5 fps; over the last bar it will be 1.0 fps. These flows will occur in the channels across each gravel bar when the Tombigbee River stage is at or below 136.5 ft.

24. Between each gravel bar will be a single pool measuring approximately 100 ft in length and 100 ft in width. The bottom elevation in each pool will be at 130 ft msl, which will be the top of the 900-ft length of fill material. It is anticipated that sedimentation will occur in these pools during all conditions of flow in the Tombigbee River. In the unlikely event that these pools fill completely with sediment during high Tombigbee River stages, a channel will always be reestablished by flowing water as stages fall and water is confined to the channel. When the river stage exceeds 137 msl, which will occur 60 percent of the time, the entire surface of each gravel bar will be covered with water (Fig. 6). The flowing water will no longer be restricted to the narrow channels on the top of each bar. When water flows out of the channels and over the gravel bar surface, the water velocities will decrease in the channels from either 1.5 or 1.0 fps, to essentially zero. When this happens, sedimentation will take place; silt and clay particles will settle on the sides of bars and in the channels cut through the top of each bar.

25. In a river such as the Buttahatchie River, which consists of a series of pools and riffles, gravel bars are usually located in the center of the channel (See Figure A1 and A2 in Appendix A). At low or normal flow, the center of the bar is exposed and water flows along one or both sides of the exposed gravel. During periods of high water, fish and other motile organisms can swim over the entire area, however at low flow mussels and other organisms live in the shallow, flowing water to the side of the bars. In the habitat complex designed for the Tombigbee River, the area receiving continuous flow is at the center of the bar, in the channels. These channels will always contain water, they will provide habitat for mussels and other aquatic species, regardless of river stage. However, if mussels and other nonmotile species migrate out of the channels and onto the surface of the bars during periods of high water, they very likely will perish when the water recedes. Therefore, it is recommended that large boulders be placed along on the surface of the bars outside

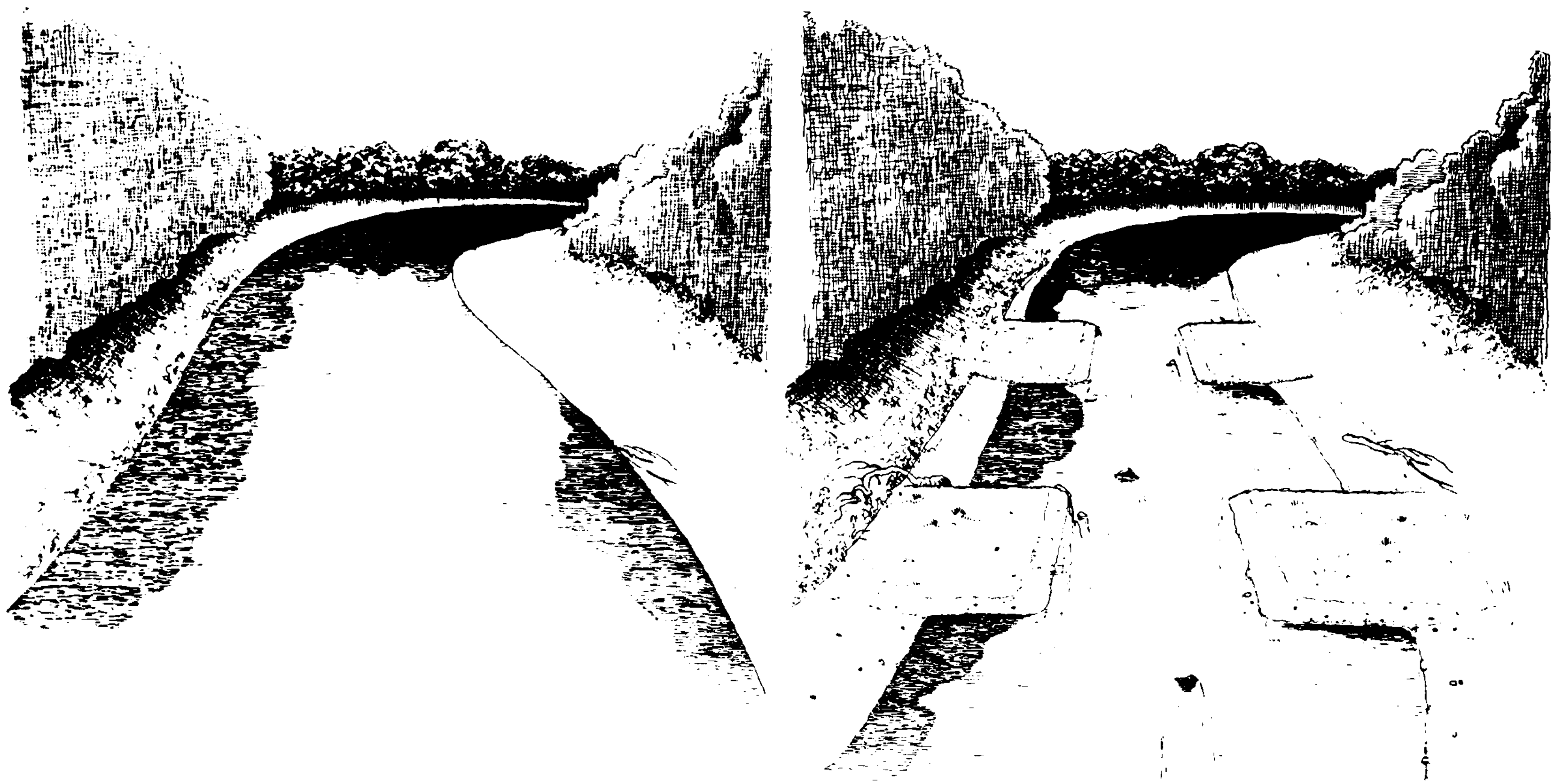

Fig. 6. Artist's conception of the response of bars I and II to conditions of high water (little or no flow) and normal to low water (water restricted to the channel across the bar). Mussels and other nonmotile organisms will inhabit the channels (visible at low water) across each gravel bar.

of the channels. Large diameter rock will provide sites of cover for small fish and will discourage lateral movement of unionid mussels.

26. When the river stage drops to 136.5 ft msl or lower, the flow over bars I-III will increase to 1.5 fps and over bar IV will be 1.0 fps. Based upon a discussion in Vanoni (1975), a flow of 1.5 fps will erode previously settled clay particles. This flow will be sufficient to remove silt or clay from the substrate but will not disturb the gravel or sand/gravel mixtures in each channel across the bar. At bar IV the flow will be 1.0 fps so some previously deposited silt or clay may not be eroded from the channel. However, as material deposits in the channel at bar IV, constriction will take place and current velocities will increase. Ultimately an equilibrium between deposition and erosion will exist in the channel at gravel bar IV; water velocities will probably eventually range between 1.0 and 1.5 fps.

27. It is anticipated that the minimum-flow release structure will always be in operation; if it should be shut down for maintenance or other purposes, flow will cease across the top of the bars. Sediments will settle that will have to be eroded away when the minimum-flow release structure is again in operation.

Suitability of the Habitat

28. The first gravel bar (Fig. 4), to be constructed of the largest sized materials (Table 1), should be suitable for large thick-shelled molluscan species that are typically found in riffle areas composed of gravel/sand substrate. Unionids which should colonize and survive in this area include *Arcidens confragosus*, *Tritogonia verrucosa*, *Quadrula quadrula*, *Plectomerus dombeyanus*, and *Amblema costata*.

29. The second gravel bar is designed to be very similar to the first, except that particle size will be smaller and more uniform. Some of the smaller mussels, such as *Pleurobema decisum*, *Obovaria* sp., *Elliptio arcus*, and possibly the status review mussel *Dysnomia* (= *Epioblasma*) *penita*, could inhabit this area.

30. The third gravel bar will be similar to the second; however, to add physical diversity, it will contain approximately 60 percent sand* by weight. This bar, like the second, would be very similar to the bar studied on the Buttahatchie River (see Appendix B) and should be suitable for common thick-shelled bivalves, such as Fusconaia ebena, Quadrula asperata, and Q. rumphiana.

31. The fourth riffle, to be composed mainly of sand, will exhibit reduced current velocities and will resemble the preferred mussel habitat defined by Kaskie (1971). This area was designed for Ligumia recta, Lampsilis anodontoides, Leptodea fragilis, and Lasmigona complanata, which typically inhabit systems with sandy substrate.

32. The pools occurring between each gravel bar will initially have a gravel or sand bottom. However, fine particulates from Columbus Lake or the Tombigbee River are expected to accumulate because of reduced to nonexistant water current. The thin-shelled mussels such as Leptodea fragilis and Anodonta grandis, as well as other slack-water inhabitants, Lampsilis straminea, Lasmigona complanata, and Proptera purpurata, should exist in these areas. The bank climber Plectomerus dombevanus, which is fairly common in riffles and pools, should also be successful in these areas.

33. Colonization of any area by mussels requires the presence of host fish or fishes suitably infected with immature clams known as glochidea.** It was determined that the majority of the mussels described in the preceding paragraphs have the correct host fish present in this section of the river. In addition, three species of unionids were taken from samplers located in the artificial substrate placed in the old bendway in 1981 (see Appendix B). It

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* Note that the gravel bar studied on the Buttahatchie River contained a fairly high percentage (0.9 to 32.9 percent) of material less than 2.0 mm in diameter (see Table B4, Appendix B).

** Recent studies by Mr. Billy G. Isom, Tennessee Valley Authority, Muscle Shoals, Alabama, cast doubt on some previous studies which suggested that each mussel requires one or more specific host fishes. Possibly certain mussels are opportunists and can use a broad range of fish species as a host. Or there may be many complex environmental variables, sensitive immune reactions, or life-cycle relationships that play a part in what was thought to be a straightforward host-specificity relationship between mussels and fish. Regardless of the outcome of this matter, which could take literally years to resolve, diverse natural fish populations are present in this river (Pennington et al. 1981) that can and have been significant in naturally propagating unionids.

is very likely that mussels will be able to naturally colonize artificially placed gravel bars in the area. This does not, however, preclude the possibility of artificially introducing either common or uncommon mussels to this site.

34. Many other nonmolluscan macroinvertebrates found in the Buttahatchie River gravel bar and on the artificial substrates placed in the old river channel of the Tombigbee River should colonize this new area after placement. These organisms will reach this habitat primarily through natural drift from upstream areas, migration from downstream areas, and/or direct oviposition by gravid females. The gravel bars should be colonized by mayflies of the families Heptageniidae, Baetidae, Siphlomuridae, Caenidae, and Leptophlebiidae. Net-spinning Trichoptera should also be abundant with representatives from the Hydropsychidae, Philopotamidae, Psychomyiidae, and Polycentropidae. Beetles of the family Elmidae should be present and dipterans such as the Chironomidae and Simuliidae should be common. Predators such as the dragonfly Gomphus and the megalopteran Corydalus should also colonize this new habitat.

35. It is anticipated that the pools would be suitable for insects such as the burrowing mayfly Hexagenia as well as the mayflies in the families Caenidae and Leptophlebiidae. Dipterans such as Chironomidae and Chaoboridae should also be abundant. Non-insectan groups such as oligochaetes, amphipods, isopods, and possibly copepods and cladocerans should also inhabit these areas.

Success of the Habitat

36. The ecological characteristics of the proposed habitat (Appendix B) were the major basis of the following predictions of the probability of success of the habitat. Other information was taken from technical literature and the results of other studies.

Sedimentation

37. This pool-gravel bar complex has been designed so that deposited sediments will be swept clear of the substrate when water levels are below 136.5 ft msl. All bottom-dwelling organisms that live on the gravel in the channels of these bars will have to be able to tolerate brief periods of sediment accumulation when slack-water conditions exist. To a certain extent these conditions normally occur in all natural rivers. The periodic accumulation and removal of suspended material in a river is tolerated by many species.

Table 2

Chemical Data Collected from the Tombigbee River Above and Below Gainesville Lock and Dam in 1978*

Parameter**	Above Gainesville Lock and Dam			Below Gainesville Lock and Dam		
	17 March	21 March	21 July	16 March	21 March	22 July
Time, hr	0845	1500	1230	1500	0945	1100
Discharge, cfs	34,300	29,600	746	34,700	30,400	2,150
Specific conductance, μmho/cm	110	85	150	131	87	156
pH	7.7	7.1	7.8	8.1	7.1	7.6
Temperature, °C	14	13	29	14.5	13.0	29.0
Turbidity, JTU	300	95	8	340	170	10
Dissolved oxygen	8.4	9.0	5.1	8.4	9.5	7.3
Total hardness	44	31	56	52	31	55
Sodium	2.4	2.4	6.1	2.6	2.2	6.2
Potassium	1.7	1.6	2.1	1.7	1.6	2.0
Total alkalinity	40	21	48	46	24	42
Dissolved solids	61	44	83	70	46	81
Ammonia nitrogen	0.10	0.06	0.08	0.10	0.07	0.10
Organic nitrogen	0.85	0.47	0.32	1.1	0.48	0.50
Dissolved phosphorus	0.02	0.03	0.01	0.04	0.03	0.02
Dissolved iron μg/ℓ	670	80	60	80	100	30
Total organic carbon	---	18.5	9.2	7.1	---	4.0
Suspended organic carbon	---	13.0	0.6	2.3	---	0.8
Dissolved organic carbon	4.8	5.5	8.6	4.8	5.8	3.2

* Information taken from Ming and Sedberry (1979).

** All values are in units of miligrams per litre unless otherwise noted.

For example, Matteson (1955) pointed out that the lighter thin-shelled species (Anodonta, Leptodea) are more able to burrow out of deposited sediment than the heavier thick-shelled species. Ellis (1936) found that the sand-inhabiting species Lampsilis teres was most readily killed by silt, while the thicker shelled Obliquaria reflexa, Quadrula quadrula, and Q. metanevra were most resistant. It is anticipated that the organisms which colonize the habitat will be able to tolerate frequent periods of sediment accumulations as they do under natural conditions. In general, it is anticipated that the thicker shelled species will be found in the channels where the water velocities are higher and the thinner shelled mussels will be found in the intervening pools.

Chemical conditions

38. Columbus Lake is still quite new, and it is difficult to predict how and to what extent this impoundment will affect the waters flowing through the minimum-flow release structure as it matures. Impoundments such as Columbus Lake often retain and alter materials such as silt and inorganic and organic nutrients (Baxter 1977). Physical and chemical studies on the water in the bendway in October 1981 indicated no particular conditions which could prove inimical to aquatic life (based on data in Fuller 1974). However, additional information on the chemical conditions of water directly below impoundments in the Tombigbee River (Table 2) and the free-flowing Tombigbee River has been obtained from the U.S. Geological Survey (USGS) to more fully assess potential impacts to gravel bar inhabitants.

39. Based upon Clarke and Berg (1959) the lower limits of water hardness as calcium carbonate for mussels in central New York is 21-47 mg/ℓ (Harman 1969). In our work on the Tombigbee River, total hardness was never lower than 57 mg/ℓ and total hardness in this river as reported by the USGS was always greater than 40 mg/ℓ (Table 2). From the standpoint of dissolved minerals, it appears that the Tombigbee River will supply more calcium than the Buttahatchie River. In addition, the presence of Columbus Lake should not decrease calcium hardness in the surface waters. Existing data from the Tombigbee River indicate that adequate calcium is present for mussels.

Water temperature

40. Upper lethal limits of water temperature for certain mussels have been reported to vary with species (Salbenblatt and Edgar 1964); based on data

by Matteson (1955), it would appear that water temperatures in the 30s (centigrade) could be harmful to some mussels. Since the minimum-flow release structure removes surface water only from Columbus Lake, there is a chance that water temperatures may be higher than typically riverine levels during July and August. However, mussels successfully inhabit man-made and natural lakes and ponds throughout the South, so there probably will not be a problem caused by water temperatures. Based on previous studies, summer maximum water temperatures in the Buttahatchie were about 30°C and in the Tombigbee River reached no more than 31°C (Howell et al. 1978). In addition, waters below Gainesville Lock and Dam on the Tombigbee River (Table 2) did not exceed 29°C.

Dissolved oxygen content

41. During a survey of the State of Mississippi, Grantham (1969) never took live mussels when dissolved oxygen was less than 3.0 mg/ℓ. During the August 1981 survey, dissolved oxygen in the bendway below Columbus Dam was measured at 9.1 and 11.8 mg/ℓ. Based on these readings and other data (Table 2); it is unlikely that dissolved oxygen will be less than 3.0 mg/ℓ at the experimental site.

Mussels habitat below dams

42. Many workers (Jenkinson, Kessler, and Clarke, Personnel Communication*; Fuller 1974) have noted that mussel beds frequently are found below dams. There are probably many reasons for the presence of mussels in these areas. First of all, the water is flowing and usually well oxygenated. Settled sediments are continuously swept clean; the area functions like a gravel bar in a river. Mussels have high requirements for flowing water because they are relatively nonmobile and need to have food in the way of particulate matter brought in to them. In addition, areas below dams are invariably populated with a large number of fish species, which can provide hosts for the immature stages of mussels. Perhaps most important is the presence of the food, both plankton and organic matter, which tends to reach high levels in the slack water above the dam. Regardless of the exact importance of each variable, it appears that the proposed site on the Tombigbee River will provide the necessary set of conditions required for successful population of mussels and other invertebrates.

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* John Jenkinson, Tennessee Valley Authority, Knoxville, Tenn.; John Kessler, US Army Engineer District Louisville, Louisville, KY; Arthur Clarke, ECOSEARCH, 7 Hawthorne St., Mattapoisett, Mass.

Corbicula

43. The Asian clam *Corbicula* was introduced into this country from the Orient in the 1930s. Since that time this clam has spread throughout much of the United States. Fuller and Imlay (1976) and Vidrine and Bereza (1976) have observed that *Corbicula* frequently invades disturbed or altered areas. Presumably, newly placed gravel bar habitat could qualify as a disturbed area and could support large numbers of *Corbicula*. The major concern is that this species could out-compete all other unionid mussels. However, it is unlikely that *Corbicula* will reach nuisance levels throughout the entire gravel bar habitat since the design plan calls for a diversity of depths, substrate types, and flow.

PART IV: SUMMARY AND RECOMMENDATIONS

Summary

44. A design for a series of four separate gravel bars with intervening slack water pools was prepared for possible placement in a bendway of the Tombigbee River at river mile 232.9 below Columbus Lake near Columbus, Mississippi. The proposed design for this habitat complex was based upon biological, physical, and chemical studies on the Buttahatchie and Tombigbee rivers. The habitat would provide proper substrate, sources of food, and cover for common and uncommon mussels and other aquatic invertebrates and vertebrates. The area for placement is out of the main navigation channel of the Tombigbee River and directly below a minimum-flow release structure located in Columbus Dam. The release structure passes 200 cfs into the upper end of the bendway. Lake water will be able to flow over the habitat complex, then down the bendway to the main navigation route that is on the Tombigbee River.

45. The gravel bars will be constructed by partially filling the upper part of the bendway at four sites with various sizes and mixtures of sand and gravel. Across the top of each gravel bar, a small channel will be cut which varies in depth from 1.5 to 4 ft and in width from 60 to 115 ft. By constricting the bendway with gravel, the river velocity will be substantially increased in these areas. The water which moves across the first three bars will be flowing at a rate of about 1.5 fps. At the fourth bar, the channel will be wider than the first three and velocities will be about 1.0 fps. It was determined that velocities of 1.5 fps would be sufficient to clear the substrate of settled sediments. The channel over the fourth bar should experience some buildup of sediments; however, equilibrium conditions should develop soon and water levels may increase and remove excess sediment. Sediment will be deposited on the gravel bars during periods of high water (greater than 136.5 ft msl), when there is backflow from the Tombigbee River. During these periods, the entire surface of each bar will be inundated and flow will be virtually nonexistent. At low-flow conditions, water will be retained in the channels on the bars; velocities will achieve 1.0 or 1.5 fps, and excessive sediments will be eroded away from the sand and gravel substrate.

46. The gravel bars will be approximately 175 ft wide and 150 ft long. To achieve the maximum habitat diversity, each bar will have a unique composition of substrate material. Gravel bar I will consist mainly of large-sized gravel and cobbles ranging from 1-5 in. in diameter. The second gravel bar will be composed of gravel ranging in size from 1-3 in. in diameter. Gravel bar III will have 40 percent 1-3 in. gravel and 60 percent sand. Gravel bar IV will have 20 percent 1-3 in. gravel and 80 percent sand. The pools between the gravel bars will have water depths no greater than 5 ft. The bottom could consist of sand or a mixture of sand and gravel initially, but after sedimentation takes place the bottom of the pools will consist mainly of silt and other settled solids.

47. Each portion of the habitat has been designed to be suitable for specific species of aquatic organisms. Those intolerant of slack water will be able to exist in the channels on top of the gravel bars. Species able to tolerant soft substrate and little or no flow should find suitable areas in the pools between the gravel bars.

Recommendations

48. Gravel bars constructed according to the plan developed as a result of this study should provide high quality habitat for a diverse community of aquatic vertebrates and invertebrates. However, the following recommendations are made to ensure maximum gain from the proposed plan.

Flexibility of design

49. It is recommended that all bars be placed in the river as a single construction effort. However, if this is not feasible due to budget or time constraints, one or two of the bars could be placed on the fill material, then the other bars placed at a later time. To ensure minimal disturbance to the aquatic habitat, the 900 ft of fill,* which forms the base material for the gravel bars, should be deposited at one time. Although the original plan depicts channels cut through the center of each bar, there is no requirement to adhere to this convention. The channels could be cut along either side or the center of the bar.

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* Fill material could consist of any stable mixture of sand and gravel.

Value of natural conditions

50. Natural sediment deposition and erosion will probably alter the characteristic of this habitat through time. In addition, aquatic plants could grow in the pools or channels over the bars and parts of terrestrial plants may be carried into the area during high water periods. These processes will not be easily reversible and probably will add to the overall value of the habitat.

Public awareness

51. Fishermen as well as others who use recreational areas generally have high interest in preserving natural resources. A display board with a brief explanatory document accompanied by on-site pictorial explanation could prove useful for explaining the purpose and value of this artificially placed habitat. A site for the display should be selected that would be seen by the public.

Relocating mussels

52. As described earlier, certain species of mussels will probably naturally colonize the habitat. Relocating certain species from nearby tributary streams should also be considered. This is a fairly easy and inexpensive process. Special attention should be paid to the status review species Dysnomia (= Epioblasma) penita, which exist in fairly high numbers in the Buttahatchie River (Appendix B).

Value of monitoring the bars

53. Because of the experimental nature of this work and its potential for use in other areas of the country, some attention should be given to periodically measuring the success of the gravel bar habitat once it is in place. This would not require a detailed or lengthy study. However, as a minimum two points are very important: (a) the hydrologic success of the bar and (b) colonization rates by aquatic invertebrates. The first item can be assessed by measuring water depths, velocities, and composition of substrates at various time periods following placement of the habitat system. Colonization rates and community structure in various parts of the bar can be measured by taking a series of quantitative benthic samples at regular time intervals for a year or more after the bars are in place. Long-term monitoring (for a period up to 10 years) would be necessary to judge the success of this habitat for mussels.

Detailed studies

54. Occasionally students in universities or colleges undertake fairly detailed long-term monitoring projects. It is possible that someone with interest in either freshwater ecology or hydrology might desire to study this system after it is in place. Such work could develop information that would augment the government-funded work and provide data to help in future plans to develop artificially placed habitats.

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APPENDIX A: METHODS AND MATERIALS USED FOR STUDIES ON THE TOMBIGBEE AND BUTTAHATCHIE RIVERS, AUGUST AND OCTOBER 1981

Physical and Chemical Determinations

1. Table A1 gives the equipment and procedures used for physical and chemical determinations.

Biological Methods

2. A stratified random sampling design was employed to select 12 benthic sampling stations in the Buttahatchie River along four transits established perpendicular to the stream (Figs. A1 and A2). Specific sampling station locations were selected by dividing each transit into numbered intervals and choosing an interval number from a table of random numbers.

3. Triplicate quantitative substrate samples were collected on 19 August 1981, with a petite ponar (232 cm^2) grab sampler at each of the 12 stations. At most stations the sampler was operated by forcing the jaws closed by hand. At stations 3, 4, 6, and 8, the grab sampler was operated from a boat because the water was too deep for wading. Each sample was placed in a wash bucket equipped with a U.S. Standard No. 30 sieve (0.595 mm) and washed in the river to remove excess debris. The remaining sediments and associated macroinvertebrates were placed in a wide-mouth plastic jar and preserved in 15-percent formalin.

4. In the laboratory, Rose Bengal dye was added to each sample to facilitate the removal of macroinvertebrates. Prior to sorting, benthic samples were placed on a No. 30 screen and washed with tap water to remove excess formalin. Macroinvertebrates were removed from the sediments with the aid of an illuminating magnifying lamp, placed in 1-1/2-oz vials, and preserved with 70-percent ethyl alcohol. A Wild M-5 stereomicroscope was used for the identification and counting of macroinvertebrates exclusive of the chironomidae and oligochaetes. Chironomid larvae and pupae were mounted on 25 mm × 75 mm glass slides using CMCP mounting medium (Pollyscience, Inc., Warrington, Pa.) and covered with 12-mm No. 2 glass cover slips. Oligochaetes were placed in lactophenol for a minimum of three weeks to clear for identification. Temporary amounts of oligochaetes were made on 25 mm × 75 mm glass slides using lactophenol as mounting medium and 18-mm No. 2 glass cover slips and identified with the aid of a compound microscope.

Table A1

Methods and Materials for Physical and Chemical Techniques Used at the Tombigbee and Buttahatchie Rivers, August and October 1981

Parameter	Equipment and Procedures
Temperature (continuous)	Taylor maximum-minimum thermometer
Temperature (discrete)	Hand-held mercury thermometer
Specific conductance and pH	Model-6 surveyor surface unit hydrolab (Hydrolab Corp., Austin, Texas)
Water velocity	Measured 6 cm above the substrate with a General Oceanics Current Meter (General Oceanics, Inc., Miami, Florida)
Total alkalinity	Model HAC-DT Hach kit
Total calcium and magnesium hardness	Model AC-DT Hach Kit
Dissolved oxygen	Modified Winkler Method, American Public Health Association (1976)
Particulate organic matter	Conducted by analytical laboratory group (WES) according to Methods for Chemical Analysis of Water and Wastes, American Public Health Association (1976).
Dissolved organic carbon	"
Total Kjeldahl nitrogen	"
Nitrate nitrogen	"
Total phosphorus	"
Orthophosphorus	"
Sodium	"
Potassium	"
Light (micro w/cm sq).	Model-268 WA underwater irradiometer (Kahl Scientific Instrument Corp., El Cajon, CA).
Suspended particulate organic matter.	Five (100-150 ml) subsamples were filtered through 0.45 Micro MHA ml filters, ashed at 475°C, and weighed with a Metler balance.

continued

Table A1 (Concluded)

Parameter	Equipment and Procedures
Sediments:	
Particle-size analysis.	Samples were oven dried at 110°C, then dry sieved through 15.9-, 2.0-, 1.0-, 0.5-, 2.25-, and 0.063-mm screens. Contents of each sieve were weighed and expressed as percentage of total sample.
Organic Matter Content	Samples were ashed to 440°C for 4 hr, then reweighed to determine percent organic matter.

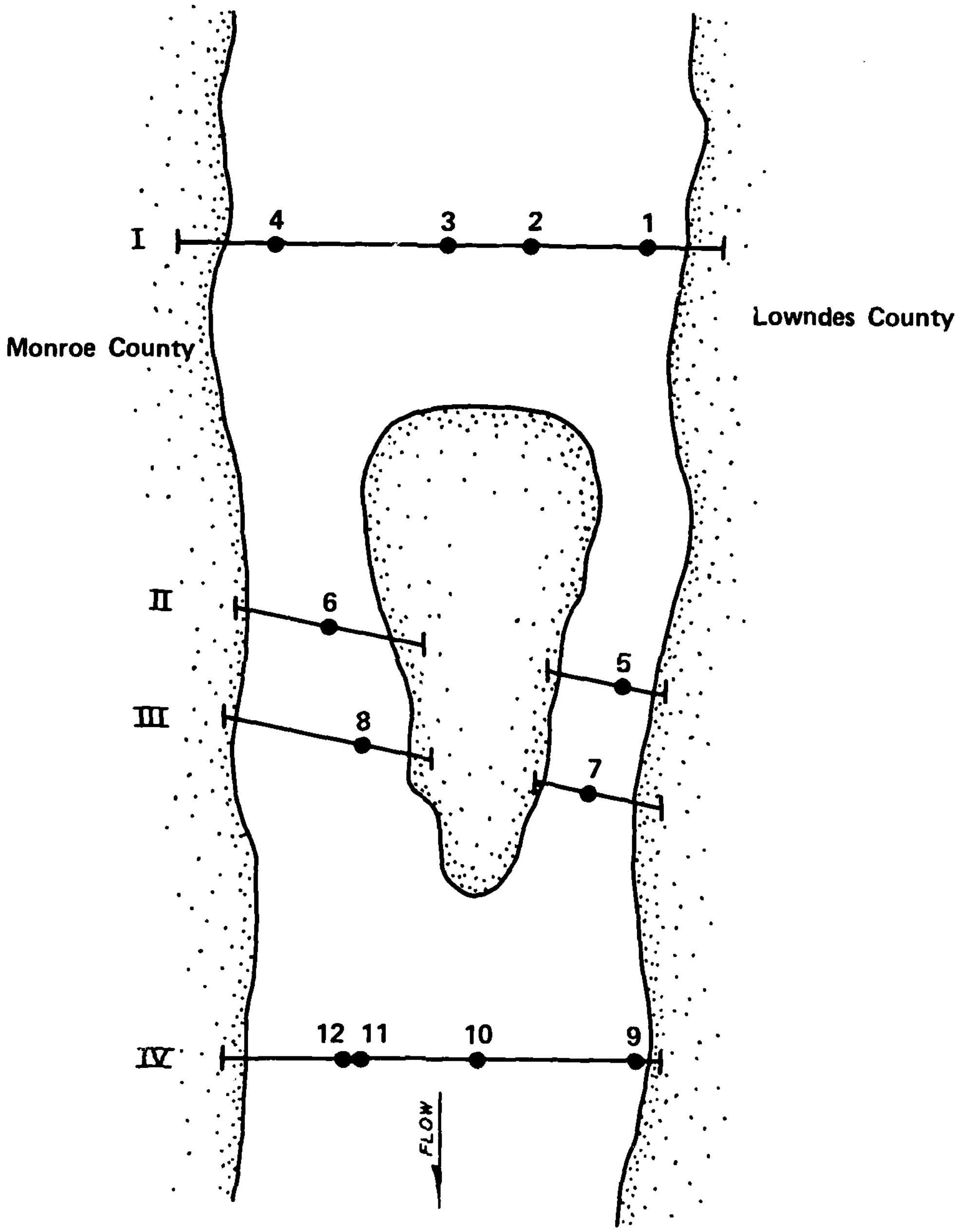

Fig. A1. Sketch map of gravel bar on the Buttahatchie River (see also Fig. 2 of the main text for a map of the Buttahatchie and Tombigbee rivers in the Columbus area).

a. View downstream from the center of the bar.

b. View upstream on the right bank.

Fig. A2. Test bar on the Buttahatchie River

5. Quantitative estimates (numbers of individuals per square meter) and species diversity (Shannon-Weaver) were calculated using a Texas Instrument (Model TI-59) programmable calculator. Placement of aquatic insects in the respective functional (feeding) groups was based upon data in Merritt and Cummins (1978), and observations of gut contents and mouth parts of the preserved insects.

6. Qualitative hand collections of macroinvertebrates (including mussels) were made in the vicinity of the gravel bar to further characterize the biota of the river system. Macroinvertebrates were collected from firm substrates such as wood and from accumulations of coarse particulate organic matter. Mussels shells were collected from middens along the river margins, and live mussels were taken from the river with the aid of rakes and by hand.

7. Artificial substrates placed in the Tombigbee River were used to determine if invertebrates were present that could colonize a new substrate and to further describe the present water quality of this area. No artificial substrate samplers were placed in the Buttahatchie River since this was not to be the site of habitat development. Triplicate artificial substrates were placed at four locations in the old river channel on 26 August and removed on 22 October 1981. Each substrate consisted of a barbecue basket filled with clean coarse gravel and cobbles. Substrates were placed on the river bottom and were held in place by tethering to a concrete block. Upon retrieval, each sampler was placed in 5-gal bucket for transport to the laboratory (about 8 hr). In the laboratory the contents of each sampler was placed on a U.S. Standard No. 30 mesh screen, and the colonizing organisms and associated debris were removed with the aid of a test-tube brush and running water. All material remaining on the screen after sieving was preserved with 80-percent ethyl alcohol. Macroinvertebrates excluding chironomids and oligochaetes were identified to the lowest possible taxonomic level. The chironomids and oligochaetes were not identified to species.

8. The following references were used in the identification of macroinvertebrates: Arnett 1973, Brinkhurst and Jamieson 1971, Burch 1973, Burks 1953, Edmundson 1959, Edmunds et al. 1976, Gooch 1967, Hilsenhoff 1975, Hiltunen 1973, Hiltunen and Klemm 1980, Johannsen 1937, Lewis 1974, Meritt and Cummins 1978, Pennak 1953, Peterson 1967, Roback 1957, Ross 1944, Stern 1976, Usinger 1963 and Wiggins 1977.

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APPENDIX B: BACKGROUND BIOLOGICAL, CHEMICAL AND PHYSICAL DATA COLLECTED FROM AN EXISTING GRAVEL BAR ON THE BUTTAHATCHIE RIVER AND AT THE GRAVEL BAR SITE ON THE TOMBIGBEE RIVER AUGUST - OCTOBER 1981

Background Information

Mussels

1. In an early mollusk investigation, Hinkley (1906) listed 37 species of unionids collected from the main stem of the Tombigbee River in Mississippi and Alabama. Major taxa obtained were in the following genera: Quadrula, Pleurobema, Eliptio, and Lampsilis. Quadrula stapes was found close to Columbus, Miss.; Pleurobema taitianium was from the Tombigbee River near Boligee, Ala.; and Pleurobema curtum was listed simply from the Tombigbee River. These three mussels are three of the five mollusks on the United States Department of Interior (USDI) status review* list (see Federal Register 11/8/80). Shells of the other two status-review species were not found.

2. The next major mollusk study for this portion of the Tombigbee River was conducted by Van der Schalie (1939), who reported the results of a collection he and Calvin Goodrich made in Columbus in 1939. They identified only 21 species and did not take any valves of the five status-review species. They blamed temporary conditions of high water, accumulated silt, and turbidity on their poor samples. Yokley (1978) surveyed the Buttahatchie River in 1977 and collected over 5,000 individuals representing at least 40 species. Sampling was conducted along the shore and in shallow water by hand and with limited diving using SCUBA. The most abundant species taken by Yokley was Quadrula asperata (34 percent), followed by Obovaria jacksoniana (19 percent), and Villosa lineosa lineosa (8 percent), and Fusconaia cerina (6 percent). The status review species Dysnomia (= Epioblasama) penita was considered common in the Buttahatchie River: 192 individuals (3.74 percent) were collected. Twenty-five mussel species were collected 4 miles upstream of the Highway 45 bridge close to the existing gravel bar evaluated for this study, (see

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* While not officially on the USDI Endangered Species List, all five species are uncommon in the study area.

Figure B1) including 25 specimens of Dysnomia (= Epioblasama) penita. Immediately below the Highway 45 bridge, 25 species were taken; 57 Dysnomia (= Epioblasma) penita were also found.

3. As part of the ecological studies for the Mobile District (U.S. Army Engineer District, Mobile 1975) workers collected mussels from 30 sites between river miles 282 and 419.5 on the Tombigbee River in October and September 1974. A total of 40 species were identified including shells of the five status-review species. Existing beds were discovered at four locations within 10 miles of the area where the Columbus Lock and Dam now exist. The most common species in their collections were Fusconaia ebena, Quadrula asperata, Obliquaria reflexa, Megalonaias gigantea, and Amblema costata.

4. On 4 September 1980, Miller (1980) collected shells and brailed for mussels at Big Creek Bendway, Hairston Bend, Rattlesnake Bend, and Cooks Bend on the Tombigbee River. At Big Creek Bendway, which is less than 15 miles down river of Columbus, Miss., 9 mussel species were collected. The most common species were Quadrula asperata, followed by Obliquaria reflexa and Fusconaia ebena. One fresh and intact shell each of Pleurobema marshalli and Pleurobema taitianum were taken. All of these specimens were collected on a sand bar (presumably the shells had been collected by muskrats) on the left bank at the downriver end of the Big Creek Bendway at river mile 305. In recent work on the Tombigbee River, Williams (1982) identified 35 unionids from the Tombigbee River in the Columbus area including four of the five status-review species.

General studies

5. In addition to the mussel studies, there have been several fairly recent biological studies conducted along the Tombigbee River near Columbus. A study of possible sources of pollution to the Tombigbee River was conducted by Cotton et al. (1969). They noted that fish kills had been recorded in the tributary streams of Tibbee, Town, and James creeks and that a reduction of water quality in Luxapalila River may have caused a slight reduction in species diversity at a site on the Tombigbee River below the confluence of this tributary. However, conditions in the tributary were localized and did not influence water quality in the Tombigbee River.

Results of Field Studies

Physical and chemical studies

6. The results of physical and chemical measurements taken on the Tombigbee River (26 August and 22 October 1981) and Buttahatchie River (20-26 August 1981) appear in Table B1. The Tombigbee River water exhibited calcium, magnesium, and total hardness and total alkalinity values that were several times greater than Buttahatchie River water. Dissolved oxygen and percent oxygen saturation values were higher in the Tombigbee River than the Buttahatchie River. Presumably this was a result of photosynthetic activity taking place in the surface waters of Columbus Lake. The turbidity levels were two to three times higher in the Buttahatchie River than the Tombigbee River. Localized showers in the upper reaches of the Buttahatchie drainage raised water levels and caused elevated turbidity values during the survey period. For Kjeldahl nitrogen, nitrate-nitrogen, total phosphorus, orthophosphate, particulate organic carbon, dissolved organic, and total organic carbon, values for both stream systems were very similar.

7. Chemical and physical data collected in the Tombigbee River were fairly similar to data collected by previous authors. For example, Pennington et al. (1981) reported that total alkalinity ranged from 27 to 53 mg/ℓ at seven specific sampling times from December 1979 through September 1980. The USGS reported that turbidity ranged from 5.0 to 65.0 in eight readings taken at river mile 321.7 (less than 10 miles from Columbus) from the period October 1977 through September 1978. Howell et al. (1978) found that pH ranged from 6.2 to 7.3 (N=10) from July 1977 through October 1977 and water temperature varied from 5.0 to 29.0°C (N=6), from April 1976 to February 1977. The higher values measured for pH during the present study were probably the results of sampling in waters that originated most recently in Columbus Lake (Table B1). During the summer increased solar radiation causes photosynthetic activity and elevated pH readings are common.

8. Light measurements were taken at a transect below the existing gravel bar on the Buttahatchie River on 1 August 1981 (Table B2). The available light reaching the stream bottom ranged from 5.1 to 17.5 percent of the surface light. These values are considerably lower than those necessary for development of photosynthetic communities. For example, McIntire et al. (1964) estimated that at least 8,000 lux was required for algae to develop in flowing water.

9. One difference between the two sites in the two river systems was the difference in percentage organic matter in suspended particulates in raw water samples (Table B3). In the Tombigbee River, the percentage of organic matter varied from two to three times that of the Buttahatchie River water. Additional organic matter in suspended sediments at the former river was probably the result of the plankton and algae in Columbus Lake. This will be an advantage for filter-feeding inhabitants of the proposed gravel bar. Filter-feeding insects are strongly influenced by the quantity and quality of particulate organic matter in suspension. The growth rates of stream chironomids is influenced by the organic content of substrates (Ward and Cummings 1979).

10. The percent composition of inorganic sediments by particle size for each station on the Buttahatchie River gravel bar is given in Table B4. This bar was dominated by gravel and cobbles with approximately 88 percent of the particles 2.0 mm in diameter or larger. The maximum diameter particles observed for sediments was approximately 150 mm. The gravel and rocks in some portion of the bar were of loose nature and were apparently subject to shifting and rolling along the stream bed. According to Hynes (1970), current velocities of 140 to 190 cm/sec can initiate the movement of coarse gravel (16 to 32 mm diameter) along a stream bed. The distribution of invertebrates is influenced by many parameters, especially the nature of the substratum (Cummings 1962, Hynes 1970). In general, larger rocks support more diverse invertebrate fauna. The looseness of rocks is also very important since loose rocks are typically colonized by fewer invertebrates than rocks embedded in the stream bottom (Hynes 1970).

Quantitative biological studies

11. The densities (number per square metre) of macroinvertebrates collected with a petite ponar on the Buttahatchie River gravel bar are listed in Table B5. The 50 taxa collected in these grab samples were dominated by members of the class insecta, which had 37 representatives. Dipterans dominated the insect group with 17 taxa, 14 of which were in the family Chironomidae. Other insectan orders included Trichoptera (8 taxa), Ephemeroptera (7 taxa), Coleoptera (3 taxa), Odonata (1 taxon), and Megaloptera (1 taxon). The class of Oligochaeta was the dominant non-insecting group with 7 taxa followed by the Pelecypoda with 4 Taxa.

12. The invertebrates collected in the quantitative samples were assigned to functional groups following Merritt and Cummings (1978). The relative composition of functional feeding groups (shredders, collectors, scrapers, and

predators) among stream invertebrates provides a useful means for describing the capacity of stream invertebrates to consume food resources (Cummings and Klug 1979). The dominant functional group (Table B6) represented on 19 August 1981 was collectors with 80 percent of the taxa, followed by predators (14 percent), scrapers (4 percent), and shredders (2 percent). The numerical dominance of collectors in this river is typical of rivers larger than the Buttahatchie that receive comparatively small amounts of allochthonous materials in the coarse particulate organic matter size category. The low numbers of scrapers indicates production by small attached algae, which again is typical of large river systems that are light limited because of high turbidity levels. It appears as though the principal organic carbon source to this reach of the Buttahatchie River is in the form of fine particulate organic matter, which is produced allochthonously and/or is of autochthonous origin and is being exported downstream.

13. Macroinvertebrate density estimates ranged from $100.6/m^2$ at stations 6 to $1408.1/m^2$ at station 5 (Table B7) with an average density of $838.1/m^2$ for the 12 stations. The most common macroinvertebrate was Corbicula fluminea, which had a mean density estimate of $292/m^2$ for the gravel bar. This filter-feeding bivalve had the greatest abundance and was found at all stations. Densities ranged from 43.1 to $948.2/m^2$. This species is very cosmopolitan and is often found in very high numbers in a wide range of water quality conditions. Aldridge and McMahon (1978) reported a mean density of $32.1/m^2$ and a maximum density of $94.5/m^2$ for C. fluminea in Lake Arlington, Texas. A density of $11{,}522/m^2$ was reported Graney et al. (1980) in a thermal discharge of the New River, Virginia. The next most abundant organism in the Buttahatchie gravel bar was the net-spinning caddis fly Chimarra sp., which had a mean density of $160.4/m^2$ and a peak density of $387.9/m^2$. This group is restricted to running waters where the larvae spin sack-like nets of silk to filter particulate matter from the currents (Wiggins 1977). The net openings for members of this family are smaller and retain small food particles than other families in North America (Wallace and Merritt 1976). Another net-spinning caddisfly, Cheumatopsyche sp., was common on the Buttahatchie River gravel bar with an average density of $39.5/m^2$. Cheumatopsyche is a member of the Hydropsychidae, which is a large and often dominant family of the caddisflies living in running water (Wiggins 1977).

14. The filter-feeding midge Glyptotendipes was also common. The other common species were collector gathers, meaning that they ingest fine particulate organic matter from the substrate with the aid of their mouth parts. Lumbriculidae sp. A. was the most predominant Oligochaete found on the gravel bar. Many members of this family of worms have a tendency to occur in stoney brooks (Brinkhurst and Jamison 1971). Stenonema spp. is a complex of possibly three species of the pulchellum group. Identification of immature forms to the species level can be made only with terminal instars, which were generally not available. S. ares, S. quinquespinum, and S. nr. Bipunctatum were, however, identified at this study site.

15. Table B7 contains diversity indices calculated from macroinvertebrates at all quantitative sampling stations. Total number of species ranged from 3 at station 6 to 22 at station 8 with a mean number per station of 11.1. Shannon-Weaver (H) values ranged from 1.15 at station 6 to 3.49 at station 8 with a mean diversity of 2.4 for the gravel bar.

Qualitative biological studies

16. The qualitative hand collections made at the gravel bar provided a few additional macroinvertebrate taxa that were not present in the grab samples, as well as a slightly different impression of the relative abundance of organisms (Table B8). These differences were the result primarily of the fact that substrates not sampled with the petite ponar, such as large sticks, logs, and tree roots and trunks, were sampled by hand. Four additional odonat species were present (Coryphaeschna sp., Didymops trinsversa, Macromia georgina, and M. alleghaniensis), as well as members of the genus Stenonema. While predaceous odonates (Didymops trinsversa and Macromia georgina) were not represented in any of the quantitative samples, they were considered to be common on the wood sampled by hand. Other common invertebrates on the wood were the predators Corydalus cornutus and Gomphus sp. It is interesting to note that the net-spinning caddis fly Chimarra sp., which was abundant in the gravel substrate, was also the most abundant macroinvertebrate on wood substrate. These observations illustrate the important of substrate such as sticks and logs to the survival of some organisms in an ecosystem such as the Buttahatchie River.

17. Artificial substrates were placed in the Tombigbee River on 26 August and allowed to colonize until 22 October 1981. The purpose of this was to determine if macroinvertebrates were present and would colonize artificially placed

gravel and cobble substrates. Macroinvertebrates removed from these substrates are listed in Table B9. Abundant taxa included members of the tribes Chironomini and Tanytarsini. Of particular interest was the presence of the following young (approximately one year or less) mussels; Leptodea fragilis, Lampsilis ornata, and Plectomerus dombeyana. These are soft-substrate quiet-water forms that should colonize the pool areas of the gravel bar when completed. The presence of these mussels on the artificial substrates indicated that environmental aspects such as dissolved oxygen, food, and fish host are adequate permitting successful colonization of mussels as well as other invertebrates.

Mussel survey

18. During three days of sampling (17, 18, 21 August) along the Buttahatchie River, 25 mussels in addition to the exotic Corbicula fluminae were collected from 4 sites (Table B10). These specimens were found on bars in the river or close to the water along the shore. Most were in good condition; the periostracum was usually not worn, and many valves were completely intact. More than half of all individuals taken were the result of fairly recent muskrat kills. The mussels were concentrated in middens or scattered in groups of less than six along the shore.

19. The Buttahatchie River mussel fauna contrasted sharply with that found in the Tombigbee River. Dominant forms in the former river were medium to small in size and were fast-water gravel-bar types such as Elliptio arcus, Quadrula aspera, Q. asperata, Q. rumphiana, and Fusconaia cerina.

20. Obovaria jacksoniana, O. unicolor, Villosa iris, and Pleurobema perovatum inhabitants of relatively clear medium-sized rivers (Starrett 1971) were fairly common in the Buttahatchie River. Species common in slow currents and soft substrates (Plectomerus dombeyana, Proptera purpurata, Leptodea fragilis, and Anodonta spp.) were uncommon or totally absent from these collections.

21. The status-review species, Dysnomia (= Epioblasama) penita, was fairly common in the Buttahatchie River samples. Yokley (1978) collected over 100 individuals of this species and considered it common. This is the only member of this genus which is known to be endemic to the Mobile River basin (Johnson 1978). Pleurobema decisium, very uncommon outside of the Buttahatchie River, was considered common to abundant in these collections.

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Table B1

Chemical Data Collected at the Test Gravel Bar on the Buttahatchie River and the Experimental Area on the Tombigbee River, August and October 1981

	Buttahatchie River		Tombigbee River	
Parameter*	20 August	26 August	26 August	22 October
Alkalinity	7.7	6.6	41.7	50.0
Total Hardness:	7.9	9.2	67.5	86.0
Calcium	3.3	5.0	61.0	57.0
Magnesium	4.6	4.2	6.5	29.0
pH	6.8	7.8	8.3	-
Dissolved oxygen	6.9	6.6	9.1	11.8
Oxygen saturation, %	87	83	120	125
Water temperature, °C	Low 25.0 High 28.0	27.0	30.0	19.0
Turbidity, NTU	40 (3)	35 (3)	12.2 (5)	22 (3)
Sodium	-	10.0	-	-
Potassium	-	2.3	1.8	-
Sulfate	-	8.0	12.0	-
Kjeldahl nitrogen	-	0.21	0.52	-
Nitrate nitrogen	-	0.28	0.051	-
Total phosphorus	-	<0.10	<0.10	-
Orthophosphate	-	0.015	<0.010	-
Particulate organic carbon	-	1.5	1.9	-
Dissolved organic carbon	-	2.7	2.7	-
Total organic carbon	-	4.2	4.6	-

* All values are in units of milligrams per litre unless otherwise noted.

Table B2

Light Readings Taken at a Transect Downriver of the Test Gravel Bar on the Buttahatchie River, August 1981

Station	Total Depth cm	Light Reading* Surface	Immediately Below Surface	Bottom	% Remaining at Bottom
1	32	2,000	1,200	350	17.5
		4,400	2,640	770	
2	58	10,800	6,600	900	8.3
		23,760	14,520	1980	
3	55	10,500	6,300	1200	11.4
		23,100	13,860	2640	
4	86	11,700	6,900	600	5.1
		25,740	15,180	1320	

* First entry for each depth at each station represents reading in $\mu w/cm^2$; second entry is in lux units.

Table B3

Suspended Particulate Organic Matter (POM) and Percentage Organic Matter in POM, Tombigbee and Buttahatchie Rivers, August and October 1981

	Buttahatchie River		Tombigbee River	
	20 August	26 August	26 Augusut	22 October
Suspended particulate Organic Matter (POM), mg/ℓ	7.8	8.5	7.8	14.6
Standard deviation	3.6	2.5	3.3	1.9
Organic content of POM, %	20.4	18.4	49.4	65.1
Standard deviation	10.2	4.1	15.1	4.4

Note N=5

Table B4

Percent Size Composition of Sediments Collected at Test Gravel Bar, Buttahatchie River, August 1981

Transect and Station		Size Category, mm - Percent Retained					
		15.9	2.0	1.0	0.5	0.25	0.063
I	1	33.2	33.2	3.0	9.2	18.9	1.8
	2	48.6	35.8	2.1	3.0	8.5	0.7
	3	33.9	57.7	3.0	1.8	2.2	0.6
	4	13.7	64.0	8.4	6.7	5.6	0.5
II	5	29.0	60.3	1.9	1.7	4.9	0.6
	6	68.2	30.6	0.6	0.2	0.1	0.0
	7	44.7	49.0	2.6	1.0	1.3	0.4
III	8	73.5	21.9	1.1	1.1	1.6	0.1
	9	15.0	76.6	1.6	1.0	3.4	1.1
IV	10	34.0	43.4	3.3	4.9	13.3	0.5
	11	55.8	36.3	2.9	1.9	1.9	0.3
	12	49.1	48.9	0.7	0.3	0.6	0.1
	13*	58.5	33.9	1.3	1.3	2.9	0.4
	14*	40.5	45.8	2.0	2.6	6.6	1.0
	$\bar{X}$ =	42.7	45.5	2.5	2.6	5.1	0.6
	SD =	17.9	15.1	1.9	2.6	5.3	0.5

* Emergent part of bar (above water).

TABLE B5

Macroinvertebrate Density Estimates from all Stations in Buttahatchie River (Numbers in Parentheses = Standard Deviations)

Taxa	Station no. - Density, $\bar{X}$ Number/m^2											
	1	2	3	4	5	6	7	8	9	10	11	12
Nematoda	- -	28.7(49.8)	- -	- -	- -	- -	- -	43.2(74.8)	- -	- -	- -	14.4(24.9)
Annelida												
Unknown annelida	- -	- -	- -	- -	- -	- -	14.4(74.P	- -	- -	- -	- -	- -
Oligochaeta												
Lumbriculidae												
spA / spB	172.4(298.6)	143.7(248.8)	100.6(138.6)	- -	86.2(149.3)	- -	129.3(114.C	57.5(99.5)	- -	- -	- -	- -
Tubificidae												
Branchiura sowerbyi	114.9(99.5)	86.2(43.1)	43.2(74.8)	- -	14.4(24.9)	- -	- -	- -	- -	- -	- -	- -
Peloscolex	- -	14.4(24.9)	14.1(24.9)	- -	- -	- -	14.4(24.9	- -	- -	- -	- -	- -
Naididae												
Dero nivea	- -	14.4(24.9)	- -	- -	- -	- -	- -	14.4(24.9)	- -	43.2(74.8)	- -	- -
Dero trifida	- -	28.7(49.8)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Unknown naididae	- -	14.4(24.9)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Pelecypoda												
Cyrenidae												
Corbicula fluminea	43.2(74.8)	43.1(0.0)	273.0(108.5)	86.2(74.4)	862.0(489.5)	71.8(89.7)	948.2(650.8	172.4(43.1)	186.8(138.6)	371.8(502.2)	287.3(99.5)	158.0(131.7)
Unionidae												
Carunculina paulus	- -	- -	- -	- -	- -	- -	14.4(24.9	- -	- -	- -	- -	- -
Amblema plicata	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	14.4(24.9)
Lampsilis straminea	- -	- -	- -	14.4(24.9)	- -	- -	- -	14.4(24.9)	- -	- -	- -	- -
Insecta												
Megaloptera												
Corydalidae												
Corydalus cornutus	14.4(24.9)	- -	28.7(24.9)	- -	- -	- -	- -	- -	- -	- -	- -	- -
Odonata												
Gomphidae												
Gomphus	- -	- -	14.4(24.9)	- -	- -	- -	- -	- -	- -	- -	- -	- -
Trichoptera												
Hydropsychidae												
Cheumatopsyche	- -	- -	28.7(24.9)	- -	14.4(24.9)	- -	14.4(24.9	28.7(24.9)	- -	172.4(224)	215.5(336.6)	- -
Macronema	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	14.4(24.9)
Philopotamidae												
Chimarra sp	- -	- -	387.9(155.4)	57.5(24.9)	- -	- -	- -	359.2(108.5)	28.7(24.9)	186.8(248.8)	273.0(326.4)	273.0(179.4)
Hydroptilidae												
Hydroptila	- -	- -	- -	14.4(24.9)	- -	- -	- -	- -	- -	- -	14.4(24.9)	- -
Glossosomatidae												
Glossosoma	- -	- -	- -	- -	- -	- -	- -	43.1(43.1)	- -	- -	- -	28.7(49.8)
Leptoceridae												
Setodes	- -	- -	- -	- -	- -	- -	- -	14.4(24.9)	14.4(24.9)	- -	- -	- -
Oecetis	- -	- -	- -	- -	- -	- -	- -	14.4(24.9)	- -	- -	- -	- -
Unknown pupa	- -	- -	14.4(24.9)	- -	14.4(24.9)	- -	- -	- -	- -	- -	- -	- -
Ephemeroptera												
Ephemeridae												
Hexagenia limbata	- -	14.4(24.9)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Caenidae												
Caenis	- -	14.4(24.9)	28.7(24.9)	- -	- -	- -	- -	28.7(24.9)	- -	28.7(24.9)	43.1(43.1)	- -
Heptageniidae												
Stenonema spp	- -	- -	114.9(49.8)	28.[illegible](24.9)	57.5(24.9)	14.4(24.)	86.2(43.1	100.6(65.8)	43.2(74.8)	28.7(24.9)	172.4(74.7)	43.1(0.0)
Stenonema nr. bipunctatum	- -	- -	14.4(24.9)	- -						- -	- -	- -
Baetidae												
Baetis	- -	- -	- -	- -	- -	- -	- -	- -	- -	14.4(24.9)	- -	- -
Siphlonuridae												
Isonychia	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	43.1(0.0)	- -
Tricorythidae												
Tricorythodes	- -	- -	- -	- -	14.4(24.9)	- -	- -	14.4(24.9)	- -	14.4(24.9)	- -	- -

* Parenthetical numbers are standard deviations.

(Continued)

TABLE B5 (Concluded)

Taxa	1	2	3	4	5	6	7	8	9	10	11	12
Coleoptera												
Elmidae												
Macronychus	- -	- -	14.4(24.9)	- -	28.7(24.9)	- -	- -	- -	- -	- -	- -	- -
Neoelmis	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	14.4(24.9)	- -
Haliplidae	14.4(24.9)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Diptera												
Simuliidae												
Unknown Simuliidae	- -	- -	- -	- -	- -	- -	- -	14.4(24.9)	- -	- -	- -	- -
Cnephia	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	14.4(24.9)
Empididae												
Hemerodromia	- -	- -	- -	- -	- -	- -	- -	- -	- -	14.4(24.9)	- -	- -
Chironomidae												
Tanypodinae												
Ablabesmyia parajanta	- -	14.4(24.9)	14.4(24.9)	- -	- -	- -	- -	14.4(24.9)	- -	- -	- -	- -
Orthocladiinae												
Orthocladius - Cricotopus Complex	14.4(24.9)	- -	- -	28.7(49.8)	- -	- -	- -	14.4(24.9)	- -	- -	28.7(24.9)	- -
Thienemanniella nr. fusca	- -	- -	- -	14.4(24.9)	- -	- -	- -	14.4(24.9)	- -	- -	- -	- -
Chironominae												
Glyptotendipes nr senilis	172.9(43.1)	316.1(221.2)	28.7(49.8)	14.4(24.9)	- -	- -	114.9(49.8)	71.8(24.9)	- -	- -	14.4(24.9)	- -
Chironomus nr. tenuicaudatus	- -	14.4(24.9)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Cryptochironomus fulvus	- -	- -	- -	- -	- -	- -	- -	14.4(24.9)	- -	- -	- -	- -
Polypedilum nr. scalaenum	- -	43.1(43.1)	14.4(24.9)	- -	- -	- -	- -	- -	- -	- -	- -	- -
P. convictus	- -	- -	- -	- -	- -	- -	- -	- -	- -	28.7(49.8)	- -	- -
P. fallax	- -	- -	- -	- -	- -	- -	14.4(24.9)	- -	- -	- -	- -	- -
Tanytarsus glabrescens Group	43.1(43.1)	143.7(89.7)	- -	- -	- -	- -	- -	14.4(24.9)	- -	- -	- -	- -
T. guerla Group	14.4(24.9)	129.3(114.0)	- -	- -	14.4(24.9)	- -	- -	28.7(24.9)	- -	- -	- -	- -
Rheotanytarsus nr. distinctissimus	- -	14.4(24.9)	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
R. exiguus	- -	- -	28.7(24.9)	- -	- -	- -	- -	- -	- -	- -	14.4(24.9)	- -
Unknown pupa	- -	- -	- -	- -	- -	- -	14.4(24.9)	- -	- -	- -	- -	- -
Total/m^2	618.0	1091.9	1149.6	258.7	1408.1	100.6	1407.9	1106.7	273.1	946.7	1135.1	560.4

Table B6

Number of Taxa and Percent Composition o' In'ertebrates Collected at a Test Gravel Bar on the Buttahatchie river, August 1981

Functional Group	Number of Taxa	Percent of Total Taxa
Collector	40	80
Gatherer	(27)	(54)
Filter-feeder	(13)	(26)
Scraper	2	4
Shredder	1	2
Predator	7	14
	50	100

Table B7

Macroinvertebrate Density, Diversity, and Equitability for Each Sampling Station

Station	Density X no./m^2	Standard Deviation SD	Coefficient of Variation CV.%	Diversity index S	Shannon Weaver Diversity, H'	Equitability EQ
1	618.0	390.7	63.3	10	2.65	0.80
2	1091.9	684.5	62.7	17	3.30	0.81
3	1149.6	248.8	21.7	17	3.03	0.74
4	258.7	74.5	28.8	8	2.64	0.88
5	1408.1	863.4	61.3	10	1.90	0.57
6	100.6	99.9	99.2	3	1.15	0.72
7	1407.9	885.7	62.9	11	1.78	0.51
8	1106.7	326.2	29.5	22	3.49	0.78
9	273.1	108.7	39.8	4	1.36	0.68
10	946.7	734.5	77.6	11	2.81	0.81
11	1135.1	305.6	26.6	12	2.76	0.77
12	560.4	197.5	35.3	8	2.07	0.69
	$\bar{X}$ = 838.1			$\bar{X}$ = 11.1	2.4	0.7

Note: At each station triplicate benthic samples were taken. The above data were generated by pooling the results of each of the triplicate samples.

Table B8

Macroinvertebrates Collected Using Qualitative Techniques at the Test Gravel Bar on the Buttahatchie River, August 1981

Taxa	Relative Abundance
Mollusca	
Corbicula fluminea	Common
Leptodea fragilis	Uncommon
Lampsilis ornata	Uncommon
Plectomerus dombeyana	Uncommon
Oligochaeta	Uncommon
Ostracoda	Uncommon
Ephemeroptera	
Ephemeridae	
Hexagenia sp.	Uncommon
Trichoptera	
Polycentropidae	
Crynellus fraternus?	Abundant
Odonata	
Coenagrionidae	Common
Gomphidae	Uncommon
Libellulidae	Common
Macromiidae	Uncommon
Diptera	
Chaoboridae	
Chaoborus sp.	Uncommon
Chironomidae	
Chironomini	Abundant
Tanytarsini	Abundant
Tanypodinae	Common
Orthocladiinae	Common

Table B9

Invertebrate Organisms Collected with Artifical Substrate Samplers in the Experimental Area of the Tombigbee River Below Columbus Dam, August-October, 1981

Taxa	Relative Abundance
Megaloptera	
Corydalidae	
Corydalus cornutus	Common
Odonata	
Aeshnidae	
Coryphaeschna*	Uncommon
Macromiidae	
Didymops transversa*	Common
Macromia georgina*	Common
Macromia alleghaniensis*	Uncommon
Gomphidae	
Gomphus	Common
Trichoptera	
Hydropsychidae	
Cheumatopsyche	Common
Macronema	Uncommon
Leptoceridae	
Setodes	Uncommon
Oscetis	Uncommon
Philopotamidae	
Chimarra	Abundant
Trichoptera	
Hydroptilidae	
Hydroptila	Common
Ephemeroptera	
Caenidae	
Caenis	Common
Baetidae	
Baetis	Common

(Continued)

* Not present in quantitative sample.

Table B9 (concluded)

Taxa	Relative Abundance
Siphlonuridae	
Isonychia	Common
Tricorythidae	
Tricorythodes	Common
Heptageniidae	
*Stenonema quinquespinum**	Uncommon
*S. ares**	Uncommon
S. nr. *bipunctatum**	Common
Coleoptera	
Gyrinidae	
*Dineutus**	Common
Elmidae	
Macronychus	Common
Neoelmis	Common
Haliplidae	Uncommon
Diptera	
Simuliidae	
Cnephia	Common
Chironomidae	
Rheotanytarsus exiguus group	Common
R. nr. *distinctissimus*	Common

Table B10

Mussel Species Collected from Five Sites, Tombigbee and Buttahatchie rivers, 17-21 August, 1981*

Species	Location: Tombigbee River: Above Luxapilia River	Tombigbee River: Below Luxapilia River	Tombigbee River: Big Creek Bendway	Buttahatchie River: Above Hwy 45	Buttahatchie River: Near Caledonia	Buttahatchie River: Below Hwy 4
Amblema plicata perplicata	X	X	--	--	--	--
Arcidens confragosus	--	--	--	--	X	--
Elliptio arcus	--	--	X	X	--	X
Elliptio crassidens	X	X	--	--	--	X
Dysnomia (=Epioblasma) penita	--	--	--	X	--	X
Fusconaia cerina	--	--	X	X	X	X
Fusconaia ebena	X	X	X	--	--	--
Lampsilis teres teres	X	X	--	X	X	X
Lampsilis ornata	X	--	--	X	--	X
Lampsilis perovalis	--	--	--	--	--	X
Lampsilis straminea	X	X	--	X	X	X
Leptodea fragilis	X	X	--	--	X	--
Megalonaias nervosa	X	X	--	--	--	X
Obliquaria reflexa	X	X	X	X	--	--
Obovaria jacksoniana	--	--	--	X	X	--
Obovaria unicolor	--	--	--	X	X	X
Plectomeris dombeyana	X	X	--	--	--	--
Pleurobema decisum	--	--	--	X	--	X
Pleurobema taitianum	X	--	--	--	--	--
Pleurobema perovatum	--	--	--	--	--	X
Potamilus (Proptera) purpuratus	X	--	--	X	--	--
Plagiola lineolat	X	X	--	--	--	--
Quadrula aspera	X	X	--	X	--	X
Quadrula asperata	X	X	X	X	X	X

(continued)

* Tombigbee River above and below Luxapalila River sampled 17 August; Buttahatchie River above Hwy 45 sampled 18, 19, 20 August; Buttahatchie River near Caledonia sampled 20 August; Buttahatchie River below Hwy 45 and Tombigbee River at Big Creek Bendway sampled 21 August 1981.

Table B10 (concluded)

Species	Location					
	Tombigbee River			Buttahatchie River		
	Above Luxapilia River	Below Luxapilia River	Big Creek Bendway	Above Hwy 45	Near Caledonia	Below Hwy 45
Quadrula rumphiana	--	X	--	X	X	X
Strophitus subvexus	--	--	--	X	--	X
Toxolasma paulus	--	--	--	X	--	--
Tritogonia verrucosa	X	--	--	X	X	X
Villosa iris	--	--	--	--	X	--
Villosa lienosa	X	--	--	X	X	--
Total species	17	13	5	18	12	18

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Miller, Andrew C.
Design of a gravel bar habitat for the Tombigbee River near Columbus, Miss. / by Andrew C. Miller, Robert H. King, and J.E. Glover (Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1983.
59 p. in various pagings : ill. ; 27 cm. -- (Miscellaneous paper ; EL-83-1)
Cover title.
"January 1983."
Final report.
"Prepared for U.S. Army Engineer District, Mobile."
Bibliography: p. 26.

1. Aquatic biology. 2. Aquatic ecology. 3. Bars (Geomorphology). 4. Gravel. 5. Tombigbee River (Miss. and Ala.) I. King, Robert H. II. Glover, J.E.

Miller, Andrew C.
Design of a gravel bar habitat for the Tombigbee : ... 1983.
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I. United States. Army. Corps of Engineers. Mobile District. II. U.S. Army Engineer Waterways Experiment Station. Environmental Laboratory. III. Title IV. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; EL-83-1.
TA7.W34m no.EL-83-1

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